Ch 10 Work, Energy, and Machines

10.1 Work and Energy

I. Work

A. By manipulating $vf^2 = v_i^2 + 2ad$ and substituting $a = (\text{Force}/\text{mass})$, you get

$$Fd = \frac{1}{2}m\,vf^2 - \frac{1}{2}m v_i^2$$

1. left side of equation describes action done to a system by external world

B. When a force is applied through a displacement work is done

1. SI unit for work is a Joule (J) which measures energy

C. Work done by constant force

1. Work = force · distance or $W = f \cdot d$
2. Constant force at angle
   a. Work = force · distance · cos θ
   b. when constant forces are perpindicular to displacement (90°), no work is done → 0

D. Work done by many forces

1. When several forces are exerted on a system, calculate the work done by each force, then add results

→ Figure 3 (p. 648)

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E. Finding work done when forces change

1. A graph of force versus displacement lets you determine the work done by a force

→ See figure 4 (p. 649)

II Energy (E) – the ability of a stystem to cause change to itself or its surroundings

A. Right side of $Fd = \underline{\frac{1}{2}mvf^2 - \frac{1}{2}m v_i^2}$ indicates in energy

B. This is represented in the work-energy theorem

a. Work = ΔE

C. Through the process of work, energy can move between the external world and a system

D. Energy associated with motion = Kinetic energy

E. Energy due to changing position = translational kinetic energy

1. Equation → $KE_{trans} = \frac{1}{2}mv^2$

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III Power - the rate at which energy is transferred

A. Equation → $P = \frac{\Delta E}{T}$

1. When work causes change in energy the equation becomes $P = \frac{W}{t}$

2. Power is measured in watts, 1 J of energy tranformed in one second

B. Power and Speed

1. When force (F_x) is in same direction as displacement $P = F \cdot v \rightarrow P = F \cdot v$

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10.1 Review

Grade: 12th

Subject: Physics

Date: 12/6

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1 The work-energy theorem states that when work is done on an object, the result is a change in _____.

B potential energy
C power
D work-energy

A kinetic energy

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2 Power is measured in ______.

A joules
B ohms
C kilo-joules

D watts

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3 How much work is done in pushing a tall box 15m with a force of 400 N, that is applied slightly upward at an angle of 10 degrees from horizontal (answer in J)?

$W = f \cdot d \cdot \cos\theta$

$\approx 5900 J$

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4 A net force, the magnitude of which is 2800 N, acclerates at 1250-kg vehicle for 8.0 s. The vehicle travels 80.0 m during this time. What power output does this represent (answer in kW)?

$P = \frac{W}{t} \rightarrow W = f \cdot d$

$W = 2800 \cdot 80 = \frac{224000 J}{8}$

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5 Jose lifts a 20 kg block to a height of 2.0 m in 5.0 s. Sue lifts 30 kg to a height of 1.5 m in 8.0 s. Which student has more power?

Jose $\underbrace{20 \cdot (9.8)}_{F} \cdot 2m = \frac{400N}{5} = 80J$

Sue $30 \cdot (9.8) \cdot 1.5m = \frac{450N}{8} = 56.2J$

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10.2 Machines

I. Benefits of Machines

A. Machines make work easier by changing the force's magnitude or direction

1. Work transfers energy

B. Mechanical Advantage (MA)

1. Equation = $MA = \frac{Fr}{Fe}$ (resistance force) / (effort force)

a. Resistance force - exerted on the machine

b. Effort force - exerted by user on machine

→ See Figure 11, p. 667

2. Ideal Mechanical Advantage (IMA)

a. Equation $IMA = \frac{de}{dr}$ displacement of the effort force / displacement of the resistance force

C. Efficiency

1. Not all input work is available as output work

a. energy leaves the system as heat or sound

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2. This is a measure of efficiency; how much/little is lost from input to output

a. Equation = $\frac{W_o}{W_i}$ $\frac{\text{(work output)}}{\text{(work input)}}$ × 100

$$\text{or} \quad e = \frac{(MA)}{(IMA)} \times 100$$

II Compound Machines

A. Most machines, no matter how complex, are a combination of one or more six simple machines: lever, pulley, wheel-axle, inclined plane, wedge, screw (Figure 12, p.668)

1. Compound machine = a machine where 2 simple machines are linked together so resistance force of first machine becomes effort force for 2nd machine

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→ see example problem 4, p.279

a. bicycle = compound machine w/ two wheel-axle systems

→ example problems 25-29, p.280

B. Multi-gear bicycle - rider can adjust gears to obtain desired IMA (adjustment of gear radius front ↔ back (high ↔ low)

1. automobile transmission works same way

III Human walking Machine

A. Levers (simple machines) give humans the ability to walk, run

B. Each system has four basic parts

1. Rigid bone
2. Source of the force (muscle contraction)
3. Fulcrum or pivot (joint)
4. A resistance (weight of body or the object lifted)

→ see Figure 18, p. 674

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Chapter 10 Review

Grade: 12th

Subject: Physics

Date: 12/12

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1 When a person walks, their hips act as a...

B piston
C pulley
D lever

A fulcrum

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2 The ratio of resistance force to effort force is called _______.

A torque

C power

D efficiency

B mechanical advantage $= \frac{F_r}{F_e}$

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3 A student lifts a box of books that weighs 215 N. The box is lifted 1.75 m. What is the change in energy (work) of the box?

W = force · distance

$215 \cdot 1.75 = 376.25$

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4 Tall people can usually walk faster than short people. Tall people must apply _______ force to move longer _______ that are their leg bones.

B greater; levers
C less; pistons
D greater; pistons

$W = f \cdot d$

$P = \frac{F \cdot d}{t}$

$P = \frac{W}{t}$

A less; levers

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5 A boy lifts a stack of six identical books from the floor to a 1.2 m high shelf in 2.5 s. If lifting the books requires 50.8 W of power, what is the mass of each book (in kg)?

d ... t ... P

$W = f \cdot d \Leftrightarrow W = f \cdot x$

$F = m \cdot a$

$P = \frac{W}{t} \longrightarrow 50.8\ W = \frac{W}{2.5}$ $W = 2.5(50.8) = 127$

$W = 127$

$\frac{127}{1.2} = \frac{1.2}{1.2} \cdot F$, $F = \frac{105.83}{9.8} = 10.79$ total mass

$10.79 / 6 = 1.8$ kg per book

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6 If the external world does work on the system, the energy of the system...

A decreases
B stays the same

C increases

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7 In which case is no work done on the ball?

A when it is dropped

C when it is lifted
D when it is pushed across a table

B when it is carried down the hall

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8 The pedals on a bicycle act as a ____.

A wheel and axle
B pulley

D wedge

C lever

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9 A player pushed a 250-g hockey puck over frictionless ice with a constant force, causing it to accelerate at 24 m/s/s over a distance of 50.0 cm. Find the work done by the hockey player on the hockey puck. Answer in joules

→ kg

$W = f \cdot d$; $F = (m \cdot a)$

250g → .25 kg
50cm → .5 m

therefore $W = (m \cdot a) \cdot d$

$W = (.25\,kg)(24\,m/s^2)(.5\,m)$

$W = 3.0\,J$ or $3\,J$

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10 From the previous problem, what is the change in kinetic energy of the puck (in J)?

$W = f \cdot d$ or $W = \Delta E$

in this case ΔE = Work on puck

therefore $\Delta E = W = 3.0\ J$ or $3\ J$ of energy (kinetic)

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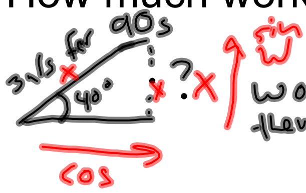
11 A ski lift carries a 75-kg skier at 3.00 m/s for 1.5 minutes along a cable that is inclined at a 40 degree angle above horizontal. How much work is done by the ski lift (answer in J)?



work is in upward direction therefore it is opposite/hypotenuse

$\sin \Theta \rightarrow \sin 40°$

Work = $\text{Force}_{lift} \cdot \text{distance}_{lift}$

Force lift = $75(9.8)$

displacement (vertical) lift = $(3 m/s)(90 s)(\sin 40°)$

Therefore $W = (75\ kg)(9.8 m/s)(3 m/s)(90 s)(\sin 40°)$

$W = 128{,}000\ J$

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12 From the previous problem, how much power is exerted by the ski lift (in kW)?

$P = \frac{W}{t}$ $\frac{128060\ J}{90 s} =$ 1.42 kW or 1420 W

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13 An electric motor lifts an elevator at a constant speed of 54 km/h. The engine must exert a force of 9.00 kN in order to balance the weight of the elevator and the friction of the elevator cable. What power does the motor produce (answer in kW)?

$\frac{54\ km}{1 h}\left(\frac{1000 m}{1 km}\right)\left(\frac{1 h}{3600 s}\right) = 15 m/s$

P = Force · velocity

P = 9,000 N · 15 m/s = 135,000 W or 135 kW

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14 Ali uses a pulley system to raise a 30-kg carton a vertical distance of 15.3 m. He exerts a force of 211 N and pulls the rope 28.0 m. What is the MA of this pulley system?

$\times 9.8 = F_{weight}$; d_r ; d_e

$$MA = \frac{F_r}{F_e}, \quad F_r = m \cdot g \rightarrow F_r = 30kg \cdot 9.8 m/s^2$$

$$F_r = 294 N$$

$$MA = \frac{294 N}{211 N} = 1.39$$

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15 From the previous problem,what is the efficiency of the system (answer is a %)?

$$e = \frac{MA}{IMA} \times 100, \quad \text{From last problem } MA = 1.39$$

$$IMA = \frac{d_e}{d_r}$$ x_e (distances) x_r

$$IMA = \frac{28m}{15.3m} = 1.83 \rightarrow e\% = \frac{MA}{IMA} \times 100$$

$$e\% = \frac{1.39}{1.83} \times 100 \rightarrow e = 76\%$$

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16 Rohit lifts a 89-kg crate by exerting a force of 120 N on a lever, through a distance of 1.6 m. The efficiency of the lever is 92%. How far is the crate lifted?

$e\% = \frac{MA}{IMA} \times 100 \rightarrow 92\% = \frac{((89kg \cdot 9.8)/(120))}{(1.6m)/(?)} \times 100$

$IMA = \frac{de}{dr}$

$MA = \frac{Fr}{Fe}$

$.92 = 7.27 / (1.6/dr)$

$.92 \times \left(\frac{1.6}{dr}\right) = 7.27$

$\left(\frac{1.6}{dr}\right) = 7.9$

$1.6 = 7.9\,dr$

$dr = .2m$

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17 A gardener lifts a 25-kg bag of sand to a height of 1.1 m, carries it across the yard a distance of 15 m and sets it down agains the wall. How much work does the gardner do when he lifts the bag (answer in J)?

$W = F \cdot d \quad 25kg \cdot 9.8 \times 1.1$

$W = 270\ J$

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18 A 300-g baseball is thrown at a speed of 6.5 m/s. The batter hits the ball and it flies into the outfield at a speed of 19.2 m/s. How much work is done in hitting the baseball (answer in J)?

$W = Ke_f - Ke_i$ or (ΔKE)

$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

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